CONTRIBUTIONS OF PRODUCTIVITY AND RELATIVE PRICE CHANGES TO FARM LEVEL PROFITABILITY CHANGE

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Abstract

This article investigates the sources of profitability and productivity change at the farm level with an application to a group of 252 farms in Kansas over an 18 years period, from 1993 to 2010. The Lowe index method is used to compute changes in total factor productivity (TFP) and terms of trade (TT). Nonparametric data envelopment analysis is used to decompose TFP into technical change and different measures of output oriented efficiency change. Profitability change is mainly driven by TFP change. The main source of TFP change is technical progress. The upward shifting efficiency frontier results in declining technical efficiency. Both profitability and productivity vary by farm size and specialization. Results point for the need to support research and development without ignoring efforts to encourage uptake of existing technologies.

Introduction

Effective public policy in the farm sector requires coherent estimates of farm performance. The US farm industry has remained very competitive requiring producers to continually make demanding production, marketing, and financial management decisions. Producers are driven towards cost competition and striving to gain scale economies by increasing farm size and adoption of new production technologies embodied in farm inputs. The Malmquist total factor productivity (TFP) index associated with Caves et al. (1982) is a dominant measure commonly used to assess the performance of farm enterprises in a dynamic setting. This measure can easily be decomposed into technical efficiency change (increase in output-input ratio due to mitigation of production mistakes) and technical change (shift in production possibility set due to increased knowledge). However, this type of analysis is entirely based on production technology and ignores farm performance judged in terms of relative output and input prices.

From a theoretical perspective, another limitation of using the Malmquist TFP index is that it is not *multiplicatively complete*, i.e., it cannot be expressed as an aggregate ratio of outputs and inputs (O'Donnell, 2012a; 2012b; 2012c). Therefore, the index cannot be decomposed exhaustively into efficiency change and technical change, and neither can efficiency change further be decomposed into measures of technical, scale, and mix efficiency. This lack of information on several components of productivity change limits our understanding of the main drivers of farm productivity, for instance, the contribution of economies of scope to productivity change. Lack of such critical information can often lead to public policy that targets the wrong drivers of productivity.

O'Donnell (2010; 2012a; 2012b) has defined several indexes that are multiplicatively complete in the sense that TFP index can be written as a ratio of aggregate output to aggregate input are exhaustively decomposed into the product of a measure of technical change and several measures of efficiency change. Those indices include Laspeyres, Paasche, Fisher, Törnqvist, and Hicks-Moorsteen. Those indexes also satisfy six important axioms from economic and index number theories: monotonicity, linear homogeneity, identity, homogeneity of degree zero, commensurability, and proportionality. However, as noted by O'Donnell (2012a) these indexes are not generally suitable for making multitemporal (i.e., many period) or multilateral (i.e., many firm) comparisons of TFP because they violate the transitivity axiom. Only the Lowe index satisfies the transitivity axiom and the other six axioms.

This study applies the Lowe aggregate quantity-price framework advanced by O'Donnell (2010;2012a) to decompose farm level profitability change into components related to change in terms of trade and productivity change which is further decomposed into economically meaningful components of efficiency and technical change. The aim of the investigation is to identify the main drivers of profitability change for a sample of Kansas farms over a period of 18 years. We also investigate the distribution dynamics of various components of profitability change in order to determine their relative importance in farm value creation. The analysis is disaggregated by farm size and specialization. Unlike the Malmquist TFP framework, this type of decomposition takes into account both the characteristics of the production technology and prices.

Recent empirical studies on samples of farms in Kansas have focused on understanding the sources of productivity growth by decomposing the Malmquist TFP into components attributable to technical change and efficiency change (Yeager and Langemeier 2011). Others have investigated sources of labor productivity growth by decomposing productivity into technical change, efficiency change, and factor intensity change (Mugera et al. 2012a) and tested for the convergence hypothesis in labor productivity (Mugera et al. 2012b). Another study focused on understanding whether technical and scale efficiency of Kansas farms is influenced by farm size and specialization (Mugera and Langemeier 2011). This study found that average technical efficiency was declining over time but it was not clear whether this was because the frontier is shifting over time, if producers are falling behind a static frontier, or a combination of both. Serra et al. (2008) investigated the influence of the decoupling of government payments on production efficiencies of a sample of Kansas farmers using a stochastic frontier model and found that an increase in decoupling would likely decrease technical efficiencies.

To the best of our knowledge, no study has investigated the effects of change in relative prices at which goods and services are exchanged (i.e., change in terms of trade) and productivity change on the change in farm level profitability. What is not clear yet is whether the ability of farm households to earn an adequate return on their resources is tied to agricultural productivity growth and whether farms are actually not improving technical efficiency. Empirical analysis on farm returns remains sparse. Productivity growth, the main focus of prior studies, is a technological relationship of how inputs are transformed into output and does not help us understand whether farms are profitable and sources of profitability.

This study contributes to the literature by applying recent advances in index numbers and nonparametric linear programming techniques to the analysis of the sources of profitability and productivity at the farm level. Sources of farm profitability are an important public policy issue to investigate because the growth and survival of many farms is tied to both profitability and productivity change.

Conceptual Framework

The framework used here incorporates both index number methods and nonparametric data envelopment analysis production function estimation methods to decompose profitability change into components attributable to changes in terms of trade and total factor productivity. The Lowe index as defined by O'Donnell (2012a) provides the basis for aggregation of inputs and outputs to compute total factor productivity. With the Lowe index, inputs and outputs are aggregated using a pre-defined farm and time invariant reference prices that are representative of prices faced by all farms. Output-oriented data envelopment analysis is used to decompose the Lowe TFP into components of technical change and several measures of efficiency change.

The measures of profitability, productivity, and productive efficiency can be illustrated in a two-dimensional space using aggregate quantities of inputs and outputs. In Figure 1, for a decision making unit (DMU) A at time period *t*, the aggregate output Q_{1t} is produced using the aggregate input X_{1t}, given the available variable returns to scale technology represented by the frontier. From an output orientation, the DMU A is not efficient in the sense that output level Q_{3t} can be achieved under the current technology without any additional input. Therefore, output oriented technical efficiency (OTE) is represented by the ratio $OTE = Q_{1t}/Q_{3t} \equiv slopeOA/slopeOC$. The maximum possible output obtainable given the input quantities and technology is represented by Q_{3t} . By construction, $0 \leq$ OTE ≤ 1 and higher values of OTE correspond to higher technical efficiency. A technically efficient DMU is one that operates on the boundary of the production frontier and an inefficient DMU is one that operates in the interior of the boundary.

Total factor productivity (TFP) for DMU A is represented by ratio $TFP_t = Q_{1t}/X_{1t} \equiv slopeOA.$ In a multi-output and multi-input framework, TFP is the ratio an aggregate output to an aggregate input. The DMU E is operating at the optimal point under a constant returns to scale (CRS) technology which also generates a higher TFP than DMU A: $Q_{2t}/X_{2t} > Q_{1t}/X_{1t}$. The frontier for the CRS technology is always linear.

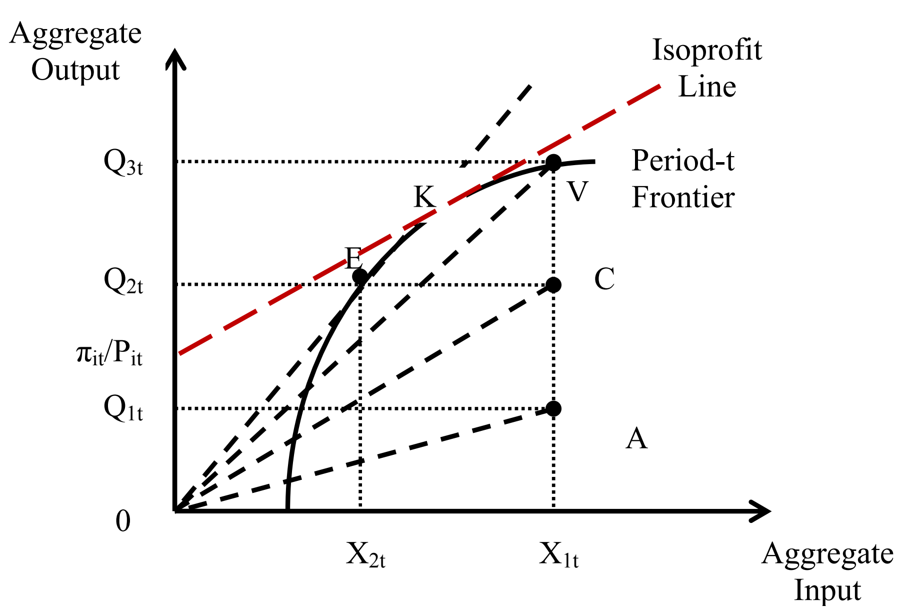

Figure 1. Measures of Efficiency and TFP

The maximum TFP under CRS occurs where the CRS frontier is tangent to the VRS frontier at point E. That is, $TFP_t^{MAX} = Q_{2t}/X_{2t} \equiv slopeOE$. Therefore, TFP efficiency for DMU A is defined as the ratio: $TFPE = TFP/TFP^{MAX} \equiv slopeOA/slopeOA$. Scale efficiency for DMU A is defined as the ratio of its TFPs under CRS to VRS when achieving full efficiency:

$OSE = (Q_{2t}/X_{2t})/(Q_{3t}/X_{1t}) \equiv slopeOE/slopeOV$. Scale efficiency is a measure of the potential gains that can be achieved through economies of scale. If DMU A holds its input vector and output mix fixed, it will be able to produce a maximum output Q_{2t}. Mix efficiency is defined at the ratio:

$OME = Q_{2t}/Q_{1t} \equiv slopeOC/slopeOV$. This is a measure of increase in TFP as a result of holding inputs fixed and relaxing restrictions on output mix (O'Donnell 2012a). The isoprofit line is represented by the line with intercept. The DMU at point K maximizes profits at aggregate prices of output and input. Given the cost of inputs and prices of output, a producer will choose to produce at point V only when inputs are relatively costless. A rational profit maximizing producer will instead choose to produce at point K where isoprofit line is tangent to production frontier. A farm manager will have to make a tradeoff of either pursuing the goal of achieving productivity or profitability by deviating from production plan K to E or V. The profit maximization problem of the farm can be represented by:

(1) $$\pi(w,p) = \max_{x,q}\{p'q - w'x : (x,q) \in T\}$$

where *p*, *q*,*w*, *x* are output prices, output quantities, input prices and input quantities. The available technology that transforms inputs into outputs is represented by *T*. From the solution to the profit maximization problem, the intercept and slope of the isoprofit line are computed as π^{Max}/p and w/p. Following the logic already presented, technical change can be represented by either an upward or inward shift of the frontier and computed as the ratio of maximum TFP under the two frontiers that represent two different production periods.

Profitability Decomposition

Let $x_{it} = (x_{1it},...,x_{Mit})'$ and $q_{it} = (q_{1it},...,q_{Nit})'$ denote the input and output quantity vectors for farm *i* in period *t*. Also let $w_{it} = (w_{1it},...,w_{Mit})'$ and $p_{it} = (p_{1it},...,p_{Mit})'$ denote the vector of input and output prices for farm *i* in period *t*. An aggregator that is nonnegative, nondecreasing, and linearly homogeneous can be used to aggregate all inputs and outputs as $X_{it} \equiv X(x_{it})$ and $Q_{it} \equiv Q(q_{it})$ respectively. Total factor productivity is defined as:

(2) $$TFP = Q_{it} / X_{it}$$

O'Donnell (2012a) refers to the TFP that can be expressed in the form of equation (2) as being *multipicately complete*. Aggregate prices of inputs and outputs can also be defined as $W_{it} = w_{it}' x_{it} / X_{it}$ and $P_{it} = p_{it}' q_{it} / Q_{it}$. Therefore, given the aggregate prices and quantities, the profitability of a farm *i* at time period *t* can be expressed as:

(3) $$PROF_{it} = (P_{it} Q_{it}) / (W_{it} X_{it}) = (Q_{it} / X_{it}) \times (P_{it} / W_{it})$$

It is apparent from equation (3) that profitability (PROF) can be decomposed into two components: total factor productivity (TFP) and terms of trade (TT).

The Lowe Quantity Index

A Lowe quantity index is the ratio of the total values of the quantities in two different time periods valued at the same set of reference prices. Here the prices are fixed and predetermined. Any set of prices may be chosen as the reference prices. They do not have to be those observed in some actual period. For example, for a longitudinal dataset, sample mean of prices can be used as reference prices. The name "Lowe Index" was introduced in the index number literature by Balk and Diewert (2003). Other competing indices used for aggregation include the Laspeyres index and Paaschers index. Compared to other indices available for aggregation, the Lowe indices are transitive and additive. These two properties are particularly attractive for making multilateral (i.e., many firms) and multitemperoal (i.e., many periods) comparisons of decision making units. The Lowe output and input indexes can be expressed as:

(4) $$Q_{it} = \sum_{i=1}^{n} p_{ob} q_{ib} \Big/ \sum_{i=1}^{n} p_{ob} q_{it} \,;\, X_{it} = \sum_{i=1}^{n} w_{ob} x_{ib} \Big/ \sum_{i=1}^{n} w_{ob} x_{it}$$

where p_{ob} and w_{ob} are the representative input and output prices at the base period *b*. O'Donnell (2012a) has shown that the Lowe output quantify index satisfies the following commonsense axioms: 1) monotonity, 2) linear homogeneity, 3) identity, 4) homogeneity of degree zero, 5) commensurability, 6) proportionality, and 7) transitivity. Other competing indexes satisfy the first 6 axioms, but not axiom 7.

The Lowe indices are transitive and can be used for multilateral comparisons of profitability and productivity indices of decision making units. This means that the Lowe index for period *t* with price reference period *s* can be written as the product of the Lowe index for period *b* with price reference period *s* multiplied by the Lowe index for period *t* with price reference period *b*: $Q_{st} = Q_{sb} \times Q_{bt}$. Thus, the Lowe index for period *t* based on the price reference period *s* can be viewed as a chain Lowe index in which periods *b* and *t* are linked through the intermediate period *s*.

The Production Technology

Given the input and output vectors, $x_{it} \in \Re_+^M$ and $q_{it} \in \Re_+^N$, the production technology available for farms in period *t* can be represented by the production possibility set:

(5) $$T(t) = \{(x,q) : x \text{ can produce q in period t}\}$$

It is assumed that the usual theoretical assumptions and regulatory properties of the production function hold[1]. The technology can be represented using the Shephard (1970) output and input distance functions as:

(6) $$D_O(x,q,t) = inf\{\delta > 0 \mid (x, q/\delta) \in T(t)\}$$

The output distance function gives the inverse of the largest factor by which a farm can scale up its output vector while holding its input vector fixed. A farm will achieve efficient input-output combination when $D_O(x,q,t) = 1$. The production function can be estimated either using stochastic frontier analysis (SFA) or data envelopment analysis (DEA). Estimation of the production function facilitates the decomposition of TFP indexes into measures of technical change and efficiency change. The DEA approach is preferred here because it is not prone to endogeneity problems associated with estimation of multiple-input and multiple-output technologies. There is also no requirement for specification of the functional form of the technology.

Efficiency Measures

Following O'Donnell (2012a), the output oriented technical efficiency is under a variable returns to scale technology is estimated by solving the following LP program:

(7) $$TE_{it}^{O} = \min_{\lambda,\theta}\{1/\lambda \mid \lambda q_{it} < Q\theta; X\theta \le x_{it}; \theta'\tau = 1; \lambda, \theta \ge 0\}$$

[1] Those properties are nonempty, closed, convex, free disposability of inputs and outputs, bounded, and weak essentiality. Satisfying those properties implies that the production function also satisfies monotonicity and quasi-concavity

where Q and X are observed output and input vectors, θ is a vector, and τ is unit column vector with the number of columns equal to the number of decision making units used to estimate the frontier in period *t*. The restriction $\theta'\tau = 1$ ensures a variable returns to scale technology. Deleting this restriction results in a constant returns to scale technology. Output oriented scale efficiency is computed by taking the ratio of the technical efficiency under CRS and VRS.

Output oriented mix efficiency is estimated by solving the following LP problem:

(8) $$ME_{it}^{O} = \min_{\theta,z}\left\{ p_o' q_{it} / p_o' z : z \le Q\theta; X\theta \le x_{it}; \theta'\tau = 1; z, \theta \ge 0 \right\}$$

where $p_o' q_{it}$ is the output aggregator function and $z = \lambda q_{it}$. This later term ensures that estimating the OTE involves estimating the maximum increase in TFP that is possible while holding the input level and output mix fixed. However, the solution to mix efficiency depends on the aggregator function and the above formula is specific for computing Lowe OME. Mix efficiency is a measure of the potential gains that can be achieved through economies of scope.

The maximum TFP possible for the TFP Lowe index using the production technology for period *t* is estimated by solving the following LP problem:

(9) $$TFP_{it}^{MAX} = \min_{\theta,z,\nu}\left\{ p_o' z : z \le Q\theta; X\theta \le \nu; w_o'\nu = 1; \theta'\tau = 1; z, \lambda, \theta \ge 0 \right\}$$

Variation of the maximum TFP across years are attributed to technical change, the inward or outward movements in the production frontier in the region of constant returns to scale.

Residual output oriented scale efficiency (ROSE) can be computed residually as the component that remains after accounting for pure technical and pure mix efficiency effects. It is a measure of the difference between TFP at an output mix-efficient point and the maximum possible TFP. Output oriented scale mixed effects (OSME) is the product of mixed efficiency and residual scale efficiency $OSME_t = OME_t \times ROSE_t$. It is a measure of productivity shortfalls associated with diseconomies of both scope and scale (O'Donnell 2012b).

Decomposition of TFP

From the foregoing, the index that compares the profitability of farm *i* in period *t* with the profitability of farm *h* in period *b* can be presented as follows:

(10) $$PROFI_{hbit} = \frac{PROF_{it}}{PROF_{hb}} = \frac{TT_{it}}{TT_{hb}} \times \frac{TFP_{it}}{TFP_{hb}} = TTI_{hbit} \times TFPI_{hbit}$$

where TTI_{hbit} is the terms of trade index and $TFPI_{hbit}$ is the TFP index for the two periods. Therefore, the average annual rate of growth in PROF, TT, and TFP in equation (10) can be calculated as

(11) $$\begin{aligned} g_{PROF} &= ln\left(PROF_{it}/PROF_{hb}\right)/\left(t-b\right); \\ g_{TT} &= ln\left(TT_{it}/TT_{hb}\right)/\left(t-b\right); \\ g_{TFP} &= ln\left(TFP_{it}/TFP_{hb}\right)/\left(t-b\right). \end{aligned}$$

This implies that annual rate of growth in PROF is the sum of the annual rate of growth in TT and TFP:

(12) $$g_{PROF} = g_{TT} + g_{TFP}\ .$$

The TFP index can be further decomposed into different efficiency measures of technical change, efficiency change, and combined scale and mix efficiency change as follows:

(13) $$TFPI_{hbit} = \frac{TFP_{it}}{TFP_{hb}} = \left(\frac{TPF_{it}^{*}}{TPF_{hb}^{*}}\right) \times \left(\frac{OTE_{it}}{OTE_{hb}} \times \frac{OSE_{it}}{OSE_{hb}} \times \frac{OME_{it}}{OME_{hb}}\right)$$

The first term in the parenthesis is a measure of technical change, the difference in the maximum TFP between two periods *t* and *b*. Therefore, a unit value will indicate no technical change. A value more than unit will indicate technical progress while a value less than unit will indicate technical regress. Other meaningful decomposition includes the TFP efficiency (TFPE) that is a ratio of TFP for farm *i* in period *t* with the maximum TFP for the same period.

(13) $$TFPE_{t} = \frac{TFP}{TFP_{it}^{MAX}} = OTE_{t} \times OSE_{t} \times ROSE_{t}$$

This measure represents the overall productive efficiency of a farm. Equation (13) implies that $TFP_{it} = TFPE_{it} \times TFP_{it}^{MAX}$. The producer with the highest TFP in each period is viewed as the best

Responsiveness of PROF to TFP Change

Since TFP represents the physical relationship between outputs and inputs that is unrelated to market prices, we use a semiparametric varying coefficient regression is used to investigate the responsiveness of PROF to TFP change. Consider the following regression

(14) $$\log(PROF_{it}) = \log(TFP_{it})\beta\left(Z_{it}\right) + u_{it}$$

where β is a vector of unknown coefficients, Z_{it} is a vector of discere covariets, and u_{it} is an error term satisfying $E(u_{it} : X_{it}, Z_{it}) = 0$. Here Z_{it} represent the different categories of farm size and specialization; this implies that β will vary with those categories. Unlike a parametric regression, the semiparametric model does not require specification of the functional form. The theoretical underpinnings of this method are detailed in Li et al. (2011).

Data Description

Data for this study was sources from the Kansas Farm Management Association. We use a balanced panel of 256 farm households for the period 1993 to 2010. The data include two outputs, crop and livestock, and five inputs: crop inputs, livestock inputs, labor, fuel and others. USDA price data for output and inputs was used to compute imputed values by dividing income or expenses by respective price indices normalized to 2010 prices. The farms are grouped according to farm size and specialization. Farm size is defined by gross farm income levels: very small farms (GFI < \$100,000); (2) small farms (\$100,000 < GFI < \$250,000; medium farms (\$250,000 < GFI < \$500,000); and large farms (GFI > \$500,000). Specialization is defined by percentage of gross farm income generated from either crop or livestock activities: livestock farms (GFI < 40%), mixed farms (40% < GFI < 80%), and diversified farms (GFI > 80%). The justification for this segregation is that the farm categories may face different constraints, which could subsequently impact efficiency measures. The summary statistics of the data are provided in Table 1.

< Insert Table 1 >

The data for the sample of farms reflects the structural change in the US farming sector. Over the sampled period, the number of farms categorized as very small and small have declined while medium and large farms have increased. The proportions of farms by farm size are: very small (18%), small (44%), medium (25%), and large (13%). Proportions by specialization are: livestock (4), mixed (27), and crop (69). The average debt to asset ratio is roughly 27% and has been declining over the sample period, from an average of 34% in 1993 to 17% in 2010. Almost all farms use debt to finance production activities.

Empirical Results

This section reports selected estimates of changes in agricultural profitability, TFP, and efficiency. All the estimates were obtained using the professional version of DPIN 3.0[2] software and several packages in R, including the np package. The farm that achieved maximum TFP in 1993, and hence maximum efficiency, was used as the reference farm. Indexes that measure the average year to year agriculture profitability, productivity, and terms of trade for 252 farms in Kansas are presented in Table 2 and Figure 2. The indexes indicate that average profitability slightly declined in the sample period. The mean, maximum, and minimum profitability was 0.666, 0.793, and 0.582. The highest profitability was realized between 1996 (0.780) and 1997 (0.793), and the lowest profitability was realized in 1998 (0.582). Those values are below unit and suggest that on average farm production value was below production cost. The highest TFP was realized in 2000 (0.912) and the lowest 1995 (0.604). Except for the year 2008, TT remained below unity suggesting that aggregate input price exceeded aggregate output price. As depicted in panel A of Figure 2, profitability has mainly been driven by both TT and TFP; an increase in TT is accompanied by a decrease in TFP and vice versa. This indicates the trade-offs that rational managers face, either to maximize profitability when TT are favorable or focus on improving productivity.

< Insert Table 2 >

< Insert Figure 2 >

Columns 5 to 7 of Table 2 provide measures of maximum TFP (TFP*), technical change (Tech), and TFP efficiency (TFPE). The maximum TFP were maximized between 1999 (2.006) and 2000 (2.217) and lowest in 1995 (1.041). Therefore, under the assumption of no technological regress, there is evidence of upward shift of the production frontier in 1997, 1999, and 2000 (see column 6). The result of this shift is a deteriorating TFP efficiency (see column 7) as most farms continue to lag behind the frontier. Panel B of Figure 2 provides a graphical illustration of this. Appendix Figure 1 plots the production frontiers for 1993 and 2010 and superimposes the isoprofit line for 2010. It is clear from the figure that most farms in 2010 still operated under the 1993 frontier while some few farms operated above this frontier.

The year to year change in the PROF, TT, and TFP does not provide an indication whether individual farms are achieving improved performance over time. Table 3 reports the indices that

[2] This software is available at http://www.uq.edu.au/economics/cepa/dpin.php

compare the profitability (PROFI), terms of trade (TTI), and TFP (TFPI) of farm *i* in each period with its PROF, TT, and TFP in 1993. Measures less than unity indicate deteriorating performance relative to 1993, unity indicate no change and greater than unity indicate improved performance. On average, farms profitability declined between 1996 and 1997 but remained above the 1993 level for the other 15 years. Terms of trade also remained above the 1993 levels except for years 1995, 1996 and 2008. However, except in 1994, 1995, 1996 , 2008 and 2010, farms TFP remained low relative to the 1993 level. Panel C of Figure 2 summarizes those results; farms generally realized improved profitability mainly driven by better TT rather than TFP. Panel D provides graphs of average growth rates of PROFI, TTI and TFPI. The average annual growth of PROFI for the 18 years is estimated to be 0.195%, which is an additive of the average annual growth of TTI (0.775%) and TFPI (-0.559%). Summary results for growth decomposition are provided in appendix Table 1.

< Insert Table 3 >

Table 4 and Figure 3 present the estimate and graphs of the efficiency components. The TFPE is decomposed into measures of output oriented technical efficiency (OTE), scale efficiency (OSE), mixed efficiency (OME), and scale mixed efficiency (OSME). There is evidence of deteriorating TFPE mainly due to a decline in OSE and OME after 2001. Again, this is traced back to the upward shift in the production frontier. This suggests that in general farms may have experienced problems related to economies of scale and scope after 2001. However, the levels of scale and mixed efficiency remained high (above 85%).

< Insert Table 4 >

< Insert Figure 3 >

The year to year measures indicate a slight decline in efficiency but this does not generally mean that individual farms did not improve their efficiency. Table 5 provides average measures of efficiency change for each farm relative to its efficiency measures in 1993. What is seen is a slight upward trend, suggesting that, farms are making progress to improve their efficiency when not measured against a shifting frontier. Average technical efficiency (OME) has remained high relative to 1993 levels, with the highest efficiency achieved in 2008. Except for the years 1997 and 1998, both scale efficiency (OSE) and mixed efficiency (OME) have remained slightly higher than 1993 levels. The scale-mix efficiency (OSME) indices reflect gains in productivity associated with economies of scale and scope. Those results are illustrated with panel B of Figure 3. Results indicate that progress in both uptake of existing, technologies adoption of new agricultural technologies, and configuration of appropriate mix and scale of operation have occurred.

< Insert Table 5 >

Analysis by Farm size and Specialization

We also analyzed how profitability and productivity differed by farm size and specialization; results are reported in Table 6 and Figures 4 and 5. On average, we find that profitability and productivity tend to increase as farms get larger. However, the differences in terms of trade (TT) are minimal as all farms tend to be price takers in the input and output markets. The difference in technical efficiency and mix efficiency tend to increase with increase in farm size too. Small and medium farms tend to be more scale efficient than very small and large farms. Figure 4 clearly shows that both profitability (PROF) and productivity (TFP) for very small and small farms has been declining while that of large farms has been increasing. The trend for medium farms seems to have remained stable. Crop farms tend to outperform mixed and livestock farms in profitability and productivity. However, livestock and mixed farms are more scale efficient than crop farms although scale efficiency tends to be very high across the specializations. Figure 3 shows that both profitability and productivity for livestock farms have been on the decline and remained fairly stable for mixed and crop farms.

< Insert Table 6 >

< Insert Figures 4 and 5 >

We used semiparametric varying coefficient regression to investigate the responsiveness of profitability to productivity change for the entire sample and across the different farm categories. Our results are reported in appendix Table 2 and show that profitability will respond positively to a positive change in productivity (0.664). The response varies by farm size with very smaller farms achieving a higher response (0.857) relative to small (0.656), medium (0.576), and large (0.585) farms. Similarly, profitability of livestock farms (0.967) will have a higher response to productivity change relative to mixed (0.744) and crop (0.613) farms.

Analysis of PROF, TFP, TT, and OTE Distributions

The results presented so far only focus on the average behavior of a representative farm in Kansas but do not reveal much change in profitability and productivity about across the entire sample. Here we use nonparametric kernel densities to compare the distribution of PROF, TT, TFP, and OTE for

1993 and 2010 as shown in Figure 6. We find that the distribution of PROF has not changed much in the two periods. However, TT experienced an entire left shift from 1993 to 2010 suggesting a decline in TT across the entire sample. This result is consistent with the results in Table 2 that indicate a decline in average TT from 1.003 to 0.902 between the two periods. Total factor productivity experienced a right shift of probability mass for the farms in the upper end of the tail suggesting that farms with initial higher TFP gained more productivity improvement while those in the lower end of the tail did not make any gains. The principle findings from those three distributions are that changes in profitability over the two periods have mainly come from gains in productivity and losses in terms of trade.

< Insert Figure 6 >

Conclusion

This article used the Lowe index to decompose farm level profitability change into measures of total factor productivity change and terms of trade change. Data envelopment analysis was also used to decompose TFP into a measure of technical change and different measures of efficiency. The analysis was disaggregated by farm size and specialization. Our results can be summarized as follows:

(1) On a year to year basis, average farm level profitability has not changed much over the sample period. The main driver of profitability has been gains in productivity which have compensated for declining terms of trade. However, relative to 1993 levels, the annual profitability growth (0.195%) is driven by growth is terms of trade (0.755%) and regress in productivity (0.559%)

(2) The main source of gains in TFP has been technical progress which has remained constant after 2000. This result is consistent with findings from prior studies that the main source of TFP change is technical change rather than efficiency change (Mugera et al. 2012a; 2012b).

(3) Levels of technical efficiency and TFPE have been declining on a year to year basis. However, this decline is because of the upward shifting production frontier. Compared to their efficiency levels in 1993, most farms have experienced improvements in technical efficiency. This observation explains why prior studies have pointed to declining technical efficiency (Mugera and Langemeier, 2011; Serra et al. 2008).

(4) On average, on a year to year basis, farms experienced a decline in scale and mixed efficiencies in the 2000's compared to the 1990's. This is an indication of diseconomies of scale and scope in production.

(5) Profitability and productivity varies by farm size with larger farms being more profitable and productive than smaller farms. Terms of trade remain comparable across the different farm sizes. In general, the profitability and productivity of smaller farms have declined over the sample period while that of medium and large farms have increased.

(6) Crops farms are more profitable and productive than mixed farms and livestock farms. The profitability and productivity of livestock farms is on the decline. However, livestock farms remain more technical efficient than mixed or crop farms.

Findings in this paper provide a snapshot of the changes taking place in the farming sector that policymakers need to be aware of. Technical progress seems to be the key driver of both profitability and productivity, hence emphasizing the importance of continuing to fund research and development. The fact that farms still continue to lag behind the best-practice frontier points to the need to continue funding efforts to help farmers uptake existing technologies. Equally important is the need to address the future survival of small farms that are likely to be driven out of farming business by declining profitability and productivity relative to large farms. Declining trends of profitability and productivity of livestock farms calls to question whether Kansas has comparative advantage in livestock production. This may point to the need for encouraging mixed enterprises or policies to improve both profitability and productivity in the livestock industry. Efforts to improve productivity of small farms and livestock enterprises will have higher payoffs in increasing profitability.

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Table 1. Descriptive Statistics, 252 Farms from 1993 to 2010

	Mean	Standard deviation	Minimum	Maximum
Crop output	333729.635	310042.351	0.000	3782372.000
Livestock output	41465.186	64829.778	0.000	1162379.000
Labour	1.382	0.796	0.200	12.000
Crop input	109276.026	103616.461	492.000	1145763.000
Fuel	36111.094	31276.306	1795.000	397159.000
Livestock input	14645.984	35424.290	0.000	833519.000
Other inputs	183022.218	130395.453	17561.000	1348123.000
Price of crop output	0.729	0.217	0.447	1.517
Price of livestock output	0.870	0.133	0.582	1.105
Price of labour	37498.704	12325.316	4651.000	231202.000
Price of crop input	0.680	0.202	0.337	1.548
Price of fuel	0.568	0.275	0.296	1.211
Price of livestock input	0.705	0.162	0.556	1.078
Price of other input	0.826	0.123	0.646	1.086

Table 2. Decomposition of Profitability Change

Year	PROF	TT	TFP	TFP*	Tech	TFPE
1993	0.684	1.033	0.664	1.217	1.000	0.664
1994	0.659	1.023	0.645	1.189	1.000	0.645
1995	0.630	1.050	0.604	1.041	1.000	0.604
1996	0.780	1.225	0.640	1.149	1.000	0.640
1997	0.793	1.003	0.791	1.402	1.152	0.687
1998	0.582	0.831	0.700	1.260	1.152	0.608
1999	0.630	0.711	0.889	2.006	1.649	0.540
2000	0.651	0.717	0.912	2.217	1.822	0.501
2001	0.622	0.752	0.835	1.617	1.822	0.458
2002	0.591	0.850	0.697	1.222	1.822	0.383
2003	0.669	0.896	0.748	1.739	1.822	0.411
2004	0.673	0.923	0.730	1.336	1.822	0.401
2005	0.617	0.722	0.861	1.587	1.822	0.473
2006	0.619	0.760	0.823	1.834	1.822	0.452
2007	0.699	0.917	0.763	1.403	1.822	0.419
2008	0.735	1.081	0.681	1.244	1.822	0.374
2009	0.683	0.878	0.777	1.305	1.822	0.427
2010	0.676	0.902	0.751	1.433	1.822	0.412

PROF, profitability; TT, terms of trade; TFP, total factor productivity, TFP*, maximum TFP; Tech, technical change, TFPE, TFP efficiency

Table 3. Profitability Change Components (1993 = 1)

Year	PROFI	TTI	TFPI	TFPI*
1993	1.000	1.000	1.000	1.000
1994	1.075	1.011	1.066	0.977
1995	1.131	0.993	1.152	0.856
1996	0.915	0.854	1.083	0.944
1997	0.894	1.034	0.868	1.152
1998	1.224	1.245	0.986	1.035
1999	1.145	1.457	0.789	1.649
2000	1.082	1.445	0.751	1.822
2001	1.143	1.382	0.834	1.328
2002	1.207	1.221	0.993	1.004
2003	1.062	1.154	0.923	1.429
2004	1.058	1.121	0.945	1.098
2005	1.144	1.438	0.798	1.304
2006	1.184	1.369	0.874	1.507
2007	1.050	1.131	0.932	1.153
2008	1.003	0.963	1.048	1.022
2009	1.115	1.180	0.940	1.072
2010	1.171	1.149	1.034	1.178

PROFI, profitability index; TTI, terms of trade index; TFPI, total factor productivity index, TFPI*, maximum TFPI.

Table 4. Components of Efficiency Change

Year	TFPE	OTE	OSE	OME	ROSE	OSME
1993	0.664	0.816	0.944	0.922	0.898	0.825
1994	0.645	0.752	0.947	0.904	0.969	0.873
1995	0.604	0.687	0.942	0.924	0.971	0.897
1996	0.640	0.722	0.947	0.910	0.998	0.905
1997	0.687	0.788	0.949	0.924	0.958	0.884
1998	0.608	0.691	0.949	0.927	0.964	0.895
1999	0.540	0.737	0.928	0.911	0.821	0.748
2000	0.501	0.714	0.911	0.902	0.802	0.722
2001	0.458	0.657	0.901	0.914	0.796	0.725
2002	0.383	0.580	0.894	0.886	0.787	0.695
2003	0.411	0.621	0.886	0.903	0.773	0.695
2004	0.401	0.647	0.882	0.867	0.766	0.658
2005	0.473	0.705	0.904	0.882	0.794	0.696
2006	0.452	0.662	0.898	0.900	0.790	0.710
2007	0.419	0.631	0.906	0.892	0.781	0.694
2008	0.374	0.566	0.893	0.895	0.784	0.699
2009	0.427	0.648	0.886	0.912	0.757	0.687
2010	0.412	0.648	0.885	0.896	0.746	0.664

TFPE, TFP efficiency; OTE, output-oriented technical efficiency; OSE, output-oriented scale efficiency,OME, output-oriented mix efficiency; ROSE, residual output-oriented scale efficiency; OSME, output-oriented scale mix efficiency.

Table 5. Efficiency Change Components (1993 = 1)

Year	TFPI	TFPI*	OTEI	OSEI	OMEI	OSMEI	ROSEI
1993	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1994	1.066	0.977	1.128	1.000	1.029	0.957	0.933
1995	1.152	0.856	1.252	1.009	1.012	0.936	0.932
1996	1.083	0.944	1.188	1.007	1.021	0.932	0.918
1997	0.868	1.152	1.070	0.998	1.006	0.951	0.948
1998	0.986	1.035	1.231	0.997	1.011	0.946	0.937
1999	0.789	1.649	1.158	1.027	1.026	1.143	1.117
2000	0.751	1.822	1.202	1.057	1.032	1.184	1.152
2001	0.834	1.328	1.325	1.082	1.017	1.200	1.189
2002	0.993	1.004	1.527	1.086	1.061	1.250	1.190
2003	0.923	1.429	1.406	1.102	1.037	1.256	1.223
2004	0.945	1.098	1.361	1.114	1.094	1.349	1.250
2005	0.798	1.304	1.226	1.064	1.067	1.241	1.177
2006	0.874	1.507	1.329	1.084	1.043	1.264	1.216
2007	0.932	1.153	1.397	1.068	1.053	1.286	1.258
2008	1.048	1.022	1.677	1.084	1.049	1.269	1.226
2009	0.940	1.072	1.379	1.087	1.028	1.348	1.449
2010	1.034	1.178	1.362	1.126	1.053	1.589	1.558

Measures are indexes that compare value for each year to base year 1993

Table 6. Decomposition by Farm Size and Specialization

	V.Small	Small	Medium	Large	Livestock	Mixed	Crop
PROF	0.473	0.650	0.744	0.842	0.482	0.621	0.695
TT	0.897	0.906	0.901	0.913	0.881	0.885	0.913
TFP	0.535	0.732	0.843	0.937	0.547	0.710	0.779
Tech	1.461	1.509	1.615	1.726	1.555	1.543	1.559
TFPE	0.393	0.514	0.545	0.556	0.371	0.483	0.523
OTE	0.642	0.638	0.717	0.819	0.851	0.719	0.658
OSE	0.859	0.964	0.916	0.814	0.933	0.946	0.900
OME	0.866	0.896	0.916	0.960	0.655	0.790	0.964

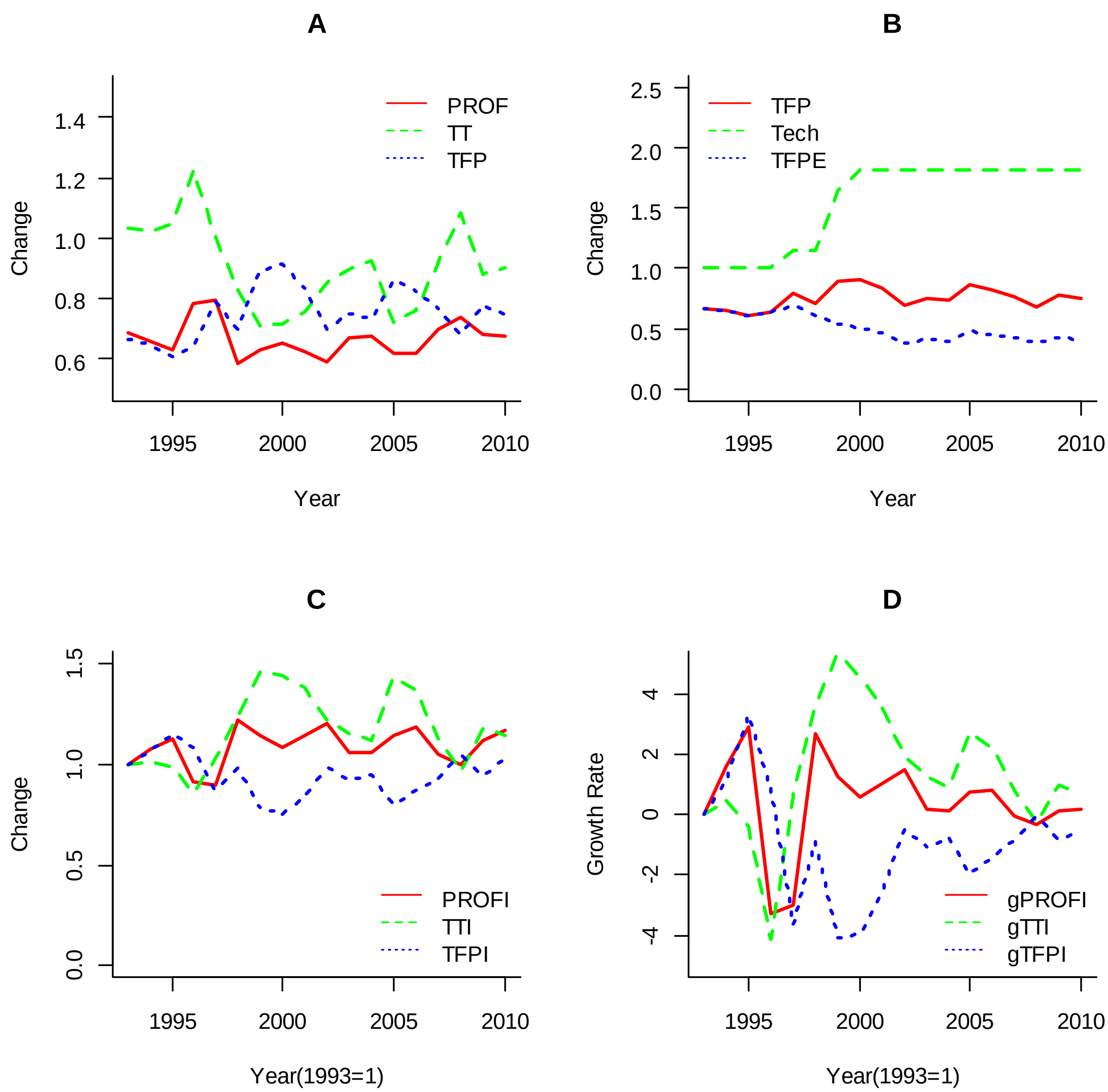


Figure 2. Productivity Change and Growth Decomposition, 1993-2010

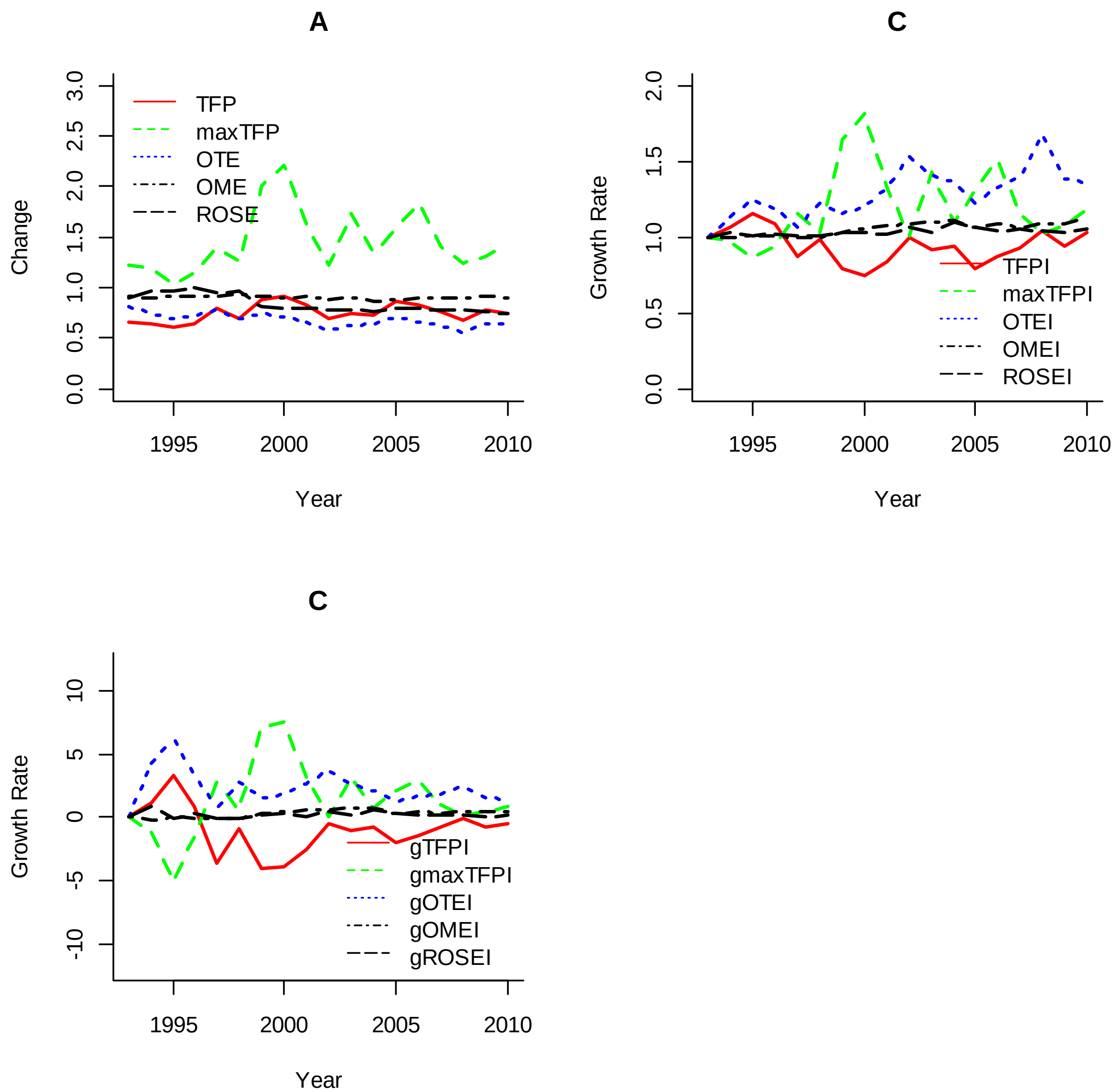


Figure 3. Decomposition of TFP into Efficiency Measures, 1993-2010

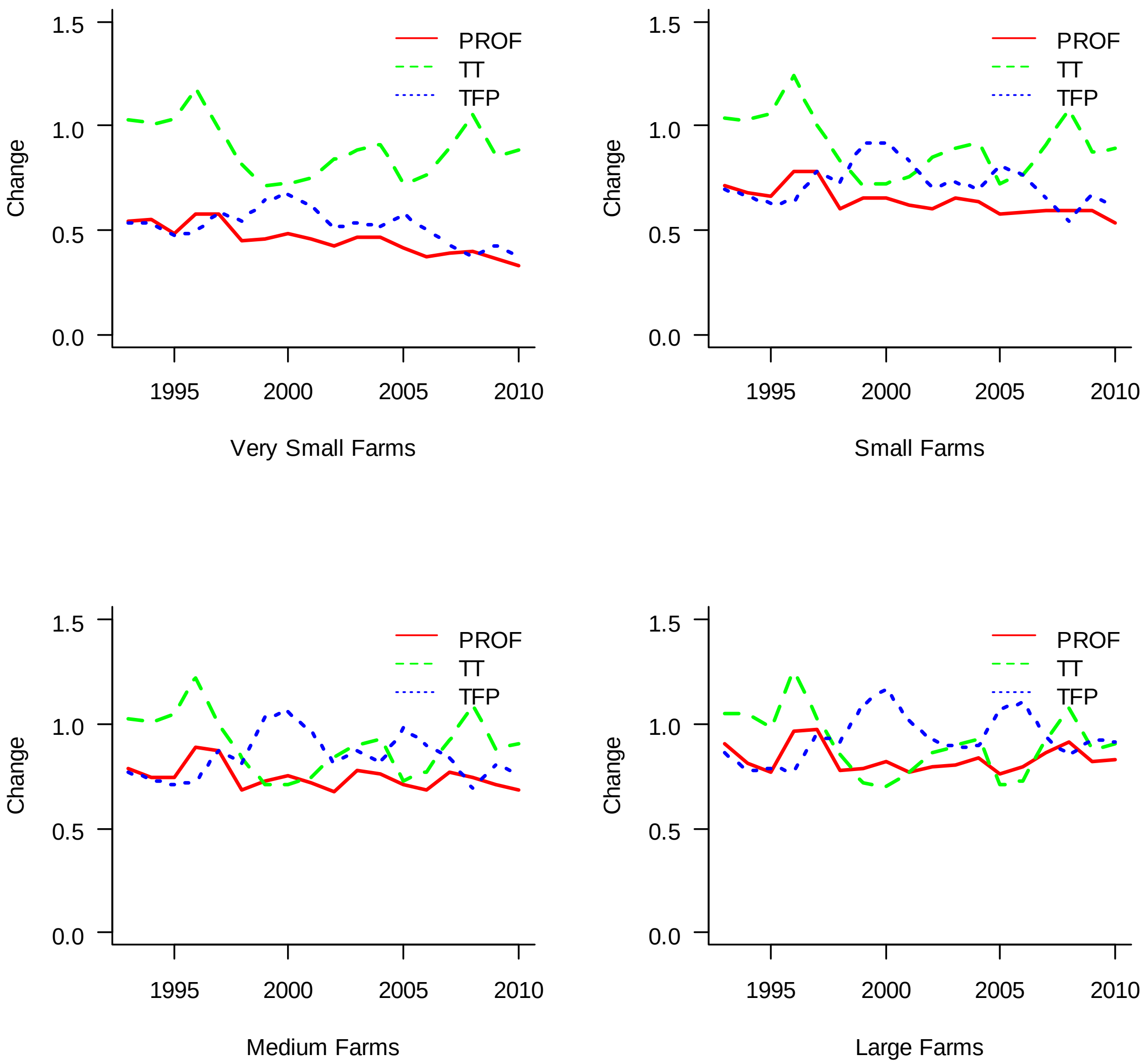


Figure 4. Productivity Change by Farm Size, 1993-2010

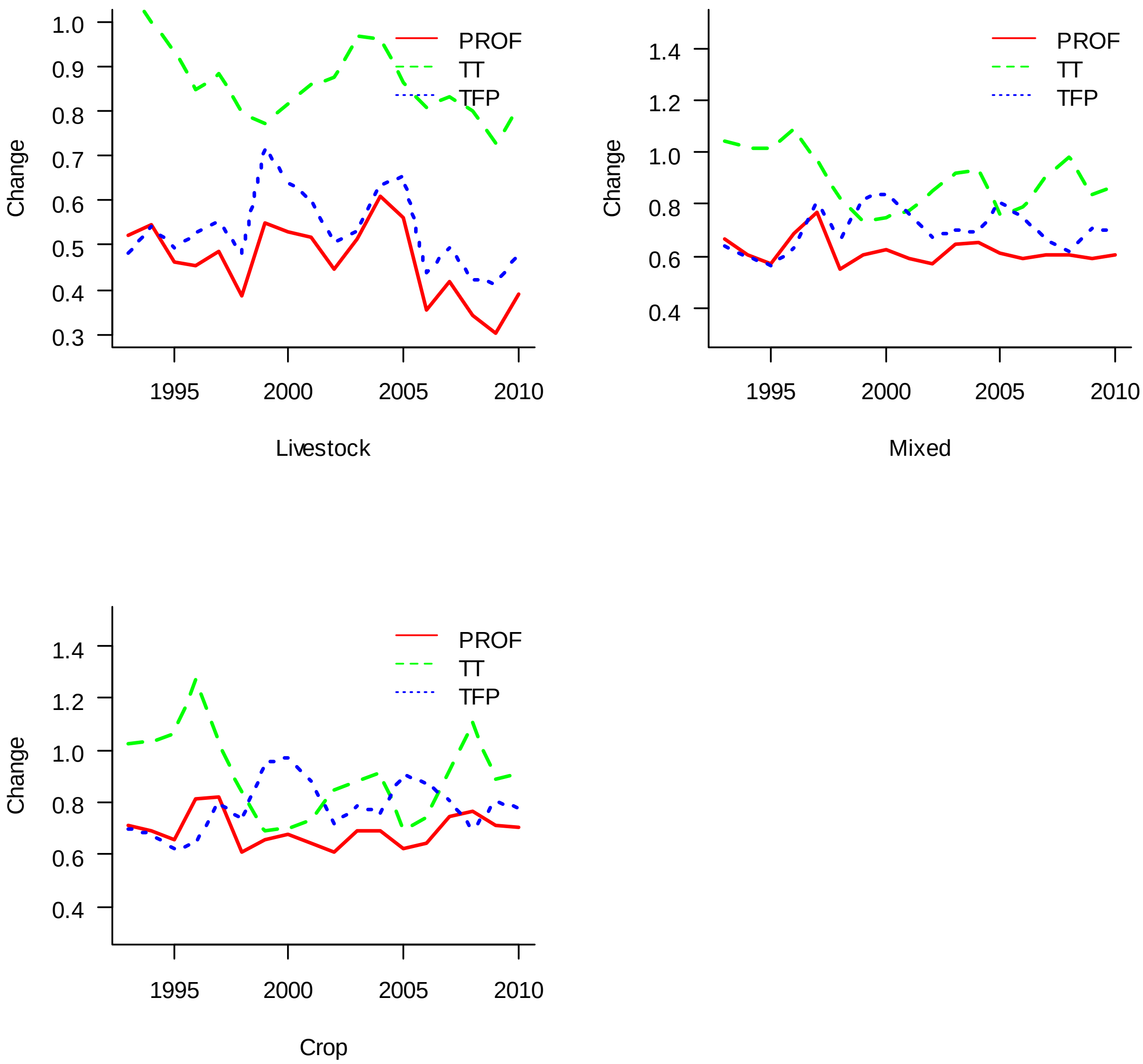


Figure 5. Productivity Change Decomposition by Farm Specialization, 1993-2010

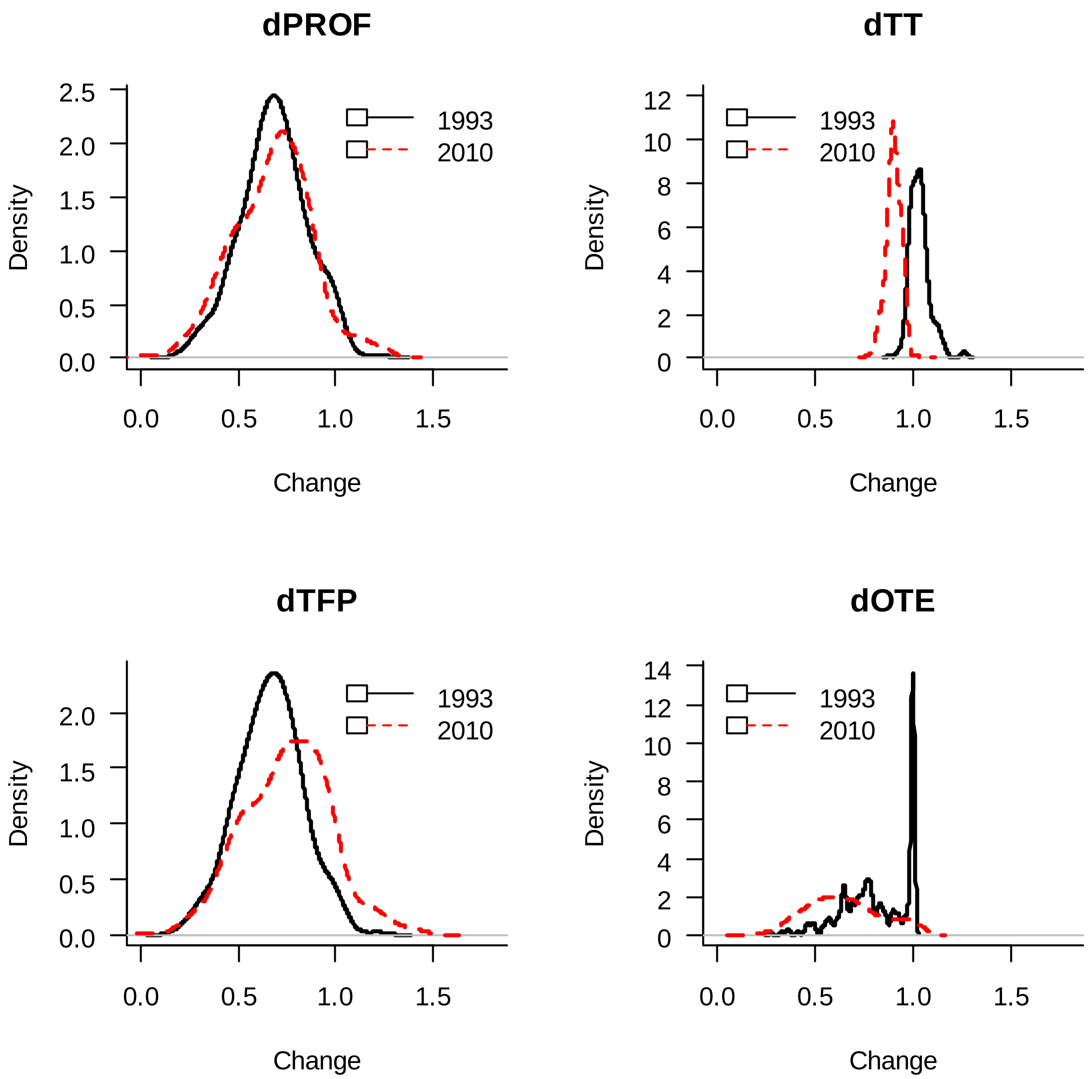


Figure 6. Productivity Change Decomposition by Farm Specialization, 1993-2010

Appendix

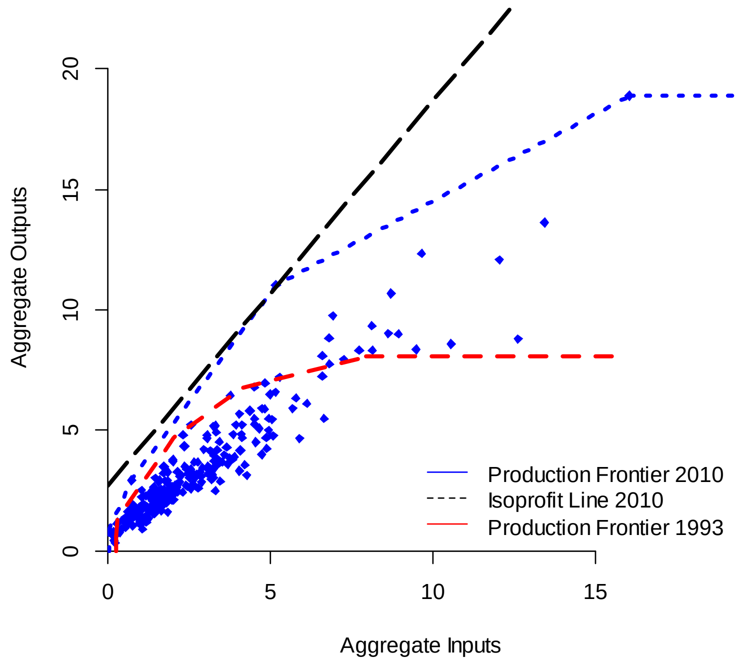
Table 1. Components of Profitability Growth (1993=1)

Year	gProfI	gTTI	gTFPI
1993	0.000	0.000	0.000
1994	1.619	0.473	1.146
1995	2.888	-0.410	3.298
1996	-3.257	-4.143	0.886
1997	-3.016	0.608	-3.625
1998	2.717	3.626	-0.910
1999	1.260	5.354	-4.094
2000	0.603	4.579	-3.977
2001	1.033	3.559	-2.526
2002	1.497	1.967	-0.470
2003	0.209	1.289	-1.081
2004	0.130	0.936	-0.806
2005	0.783	2.772	-1.989
2006	0.800	2.216	-1.417
2007	-0.033	0.802	-0.835
2008	-0.314	-0.270	-0.044
2009	0.133	0.956	-0.823
2010	0.195	0.755	-0.559

Growth in profitability is a sum of growth in terms of trade and total factor productivity

Table 2. Elasticity of PROF to TFP by Farm Category

	Intercept	log.TFP
All Farms	-0.234	0.664
Very Small	-0.254	0.857
Small	-0.266	0.656
Medium	-0.218	0.576
Large	-0.127	0.585
Livestock	-0.163	0.967
Mixed	-0.247	0.744
Crop	-0.233	0.613



Appendix Figure 1. Empirical Production Functions under VRS and Isoprofit Line 2010